United States Patent [19]

Seal

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[45] **Date of Patent: * Dec. 25, 1984**

[54] **MICROCOMPUTER CONTROLLED DEMAND/SCHEDULED WATER SOFTENER**

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[73] Assignee: **Autotrol Corporation**, Milwaukee, Wis.

[*] Notice: The portion of the term of this patent subsequent to Jan. 17, 2001 has been disclaimed.

[21] Appl. No.: **511,876**

[22] Filed: **Jul. 8, 1983**

Related U.S. Application Data

[63] Continuation of Ser. No. 412,279, Aug. 27, 1982, Pat. No. 4,426,294.

[51] **Int. Cl.**[3] **B01J 49/00**

[52] **U.S. Cl.** **210/89**; 210/98; 210/140; 210/143; 364/502

[58] **Field of Search** 210/662, 670, 687, 89, 210/98, 102, 103, 109, 140, 143, 190, 191, 269; 364/500, 502

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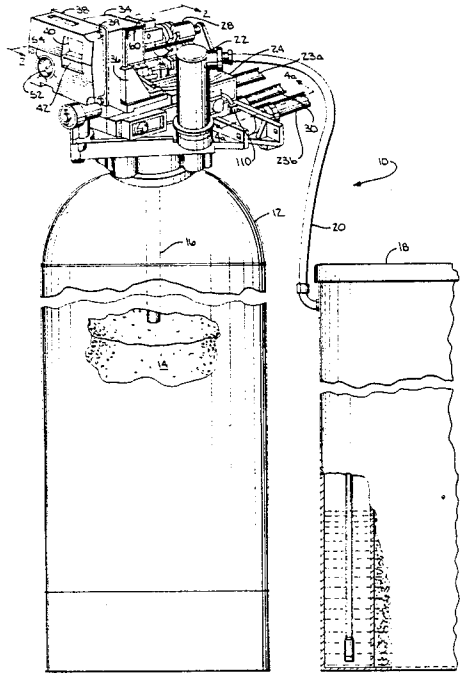
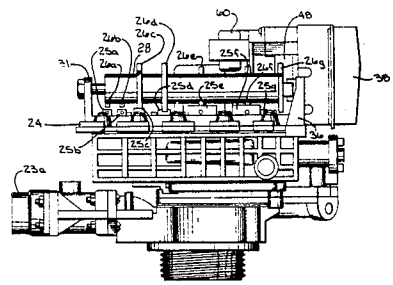
Primary Examiner—Ivars C. Cintins
Attorney, Agent, or Firm—Quarles & Brady

[57] **ABSTRACT**

An improved control for a resin bed water softener includes a microcomputer which is supplied with input data from a flowmeter indicative of the quantity of soft water leaving the softener. In accordance with the flow data, the microcomputer determines the amount of water used since the last regeneration and also determines the average daily soft water consumption. The microcomputer also coupled to a data input device and receives input data indicative of the total resin bed treating capacity and the incoming water hardness. At a prescribed hour each day, the microcomputer determines the remaining water softener resin bed treating capacity as calculated from the water hardness, the total resin bed treating capacity and the amount of water used since the last regeneration. The remaining resin bed treating capacity is compared to the reserve established as a proportion of the average daily consumption of soft water and regeneration is initiated when the reserve is greater than the remaining resin bed treating capacity.

7 Claims, 9 Drawing Figures





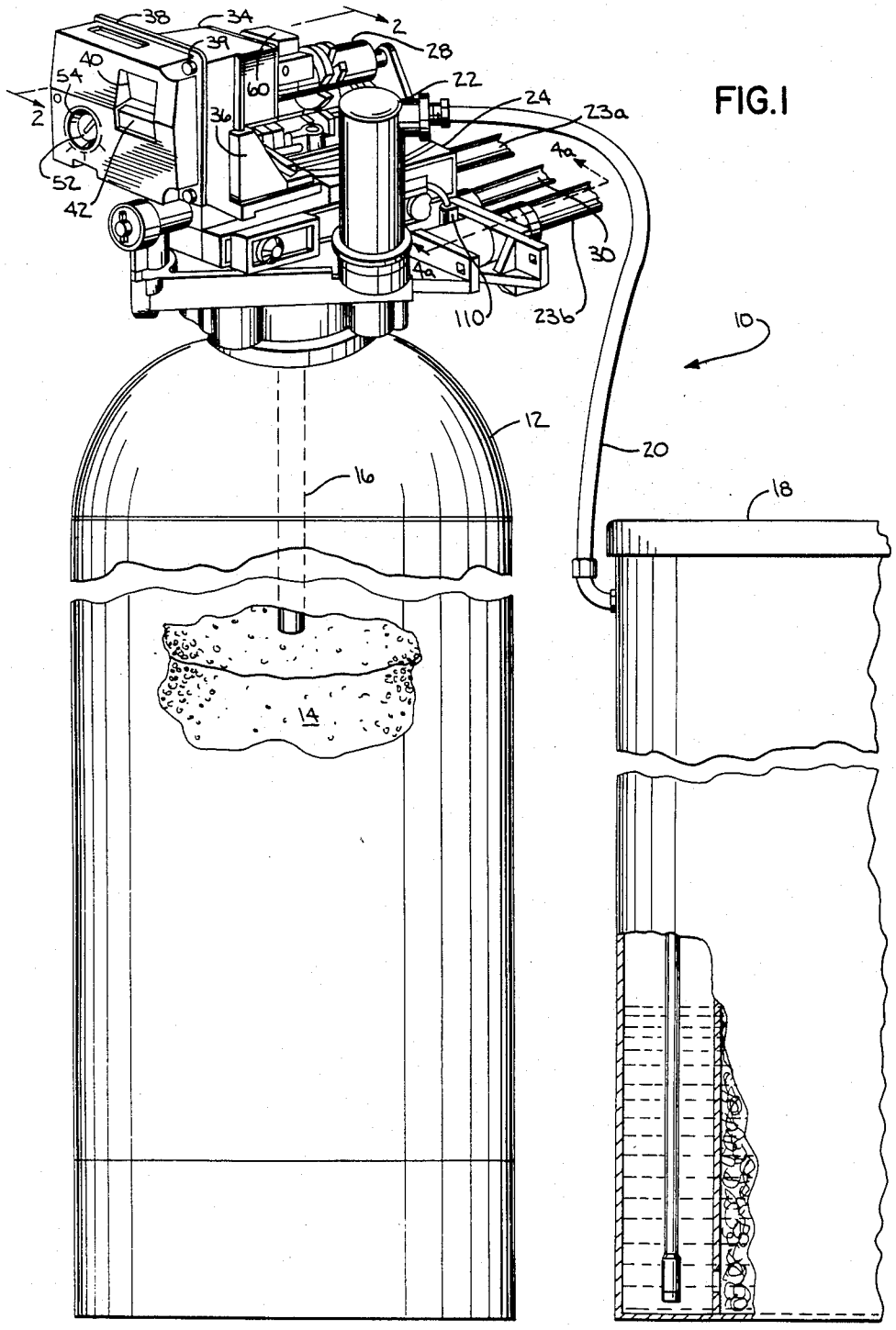
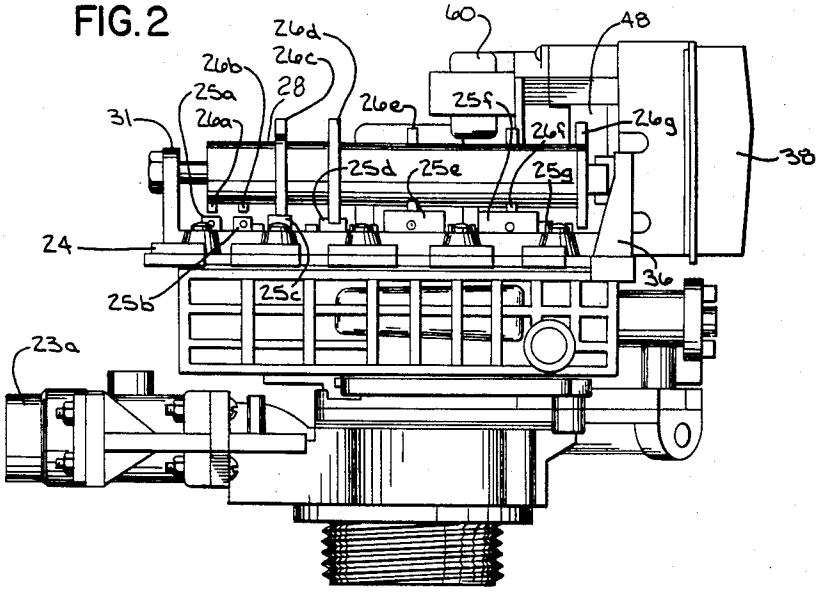

38
34
2
39
28
40
54
60
22
24
23a
2
36
4a
52
42
30
4a
110
23b
10
12
20
16
18
14

FIG.1

FIG. 2


60
48
26d
26c
26b
28
25a
26a
31
26e
25f
26f
26g
38
25d
25e
25g
24
36
25b
25c
23a

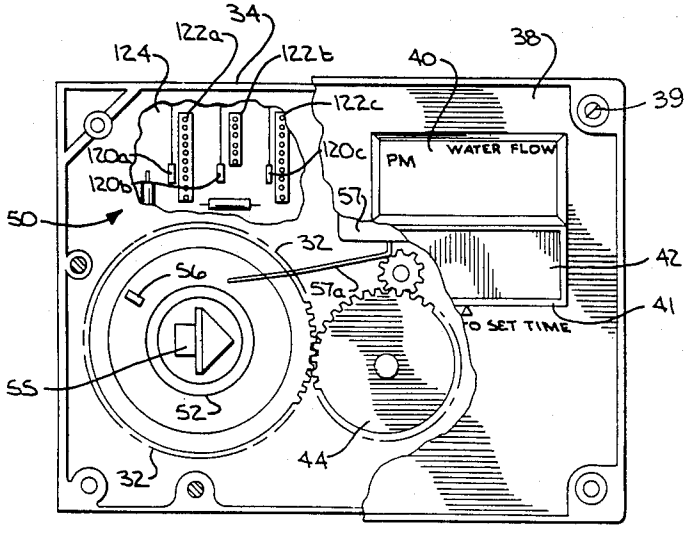

34
122a
124
122b
40
38
39
122c
120a
120b
120c
PM
WATER FLOW
57
50
32
42
56
57a
41
TO SET TIME
55
52
44
32

FIG. 3

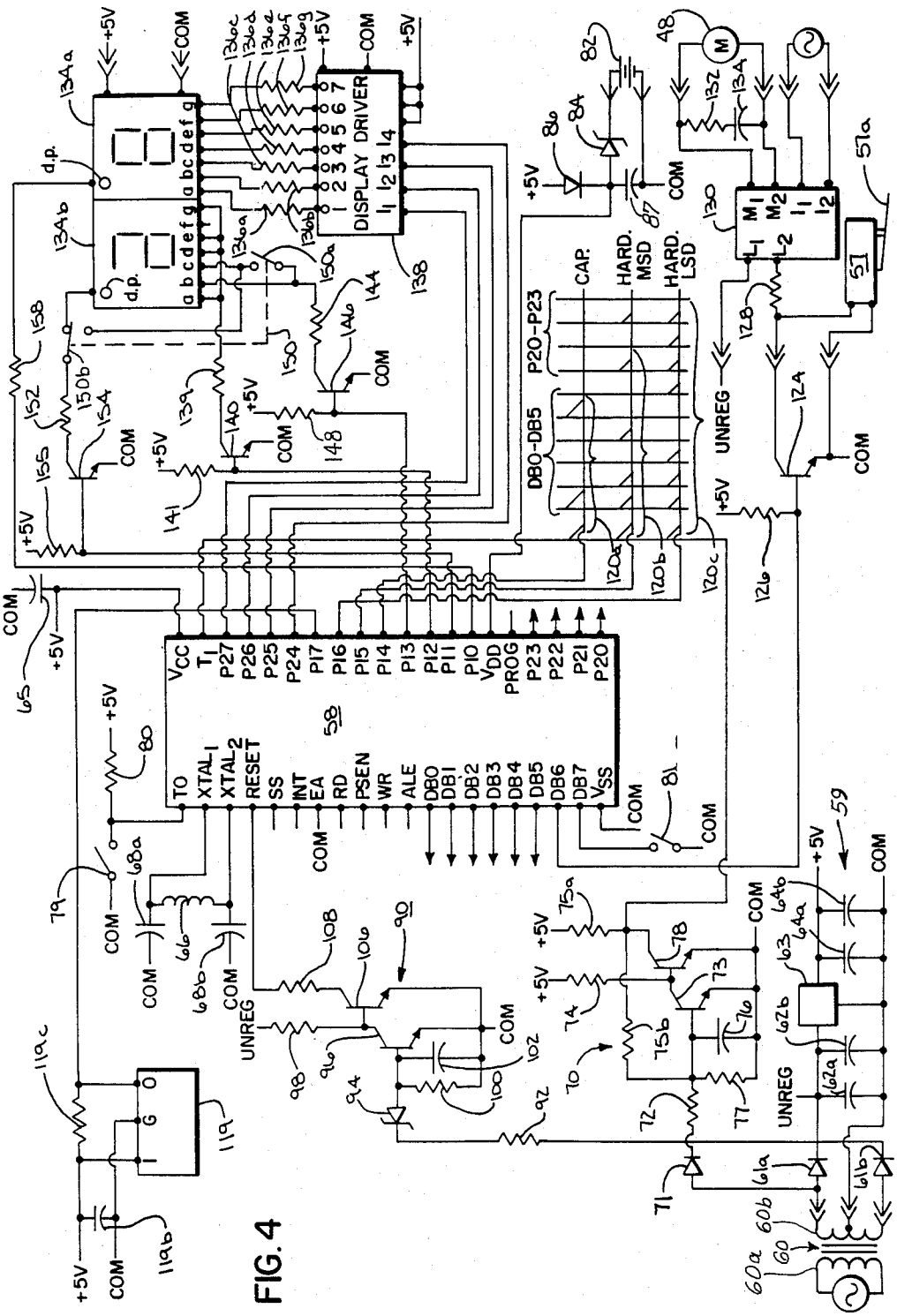

DISPLAY DRIVER
DBO-DB5
P20-P23
CAP.
HARD. MSD
HARD. LSD
UNREG
COM
+5V
VCC
T1
P27
P26
P25
P24
P17
P16
P15
P14
P13
P12
P11
P10
VDD
PROG
P23
P22
P21
P20
TO
XTAL1
XTAL2
RESET
SS
INT
EA
RD
PSEN
WR
ALE
DB0
DB1
DB2
DB3
DB4
DB5
DB6
DB7
VSS
M1
M2
d.p.

FIG. 4

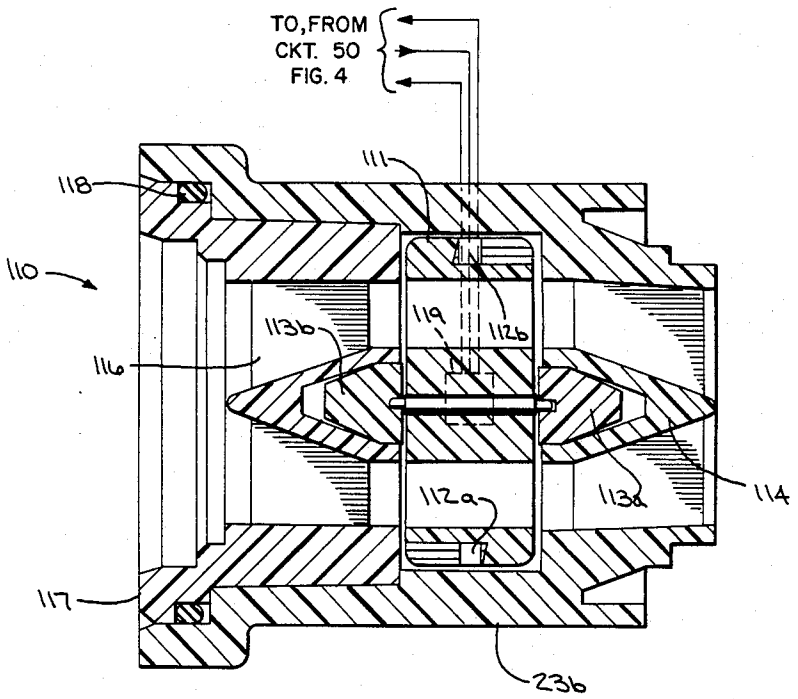
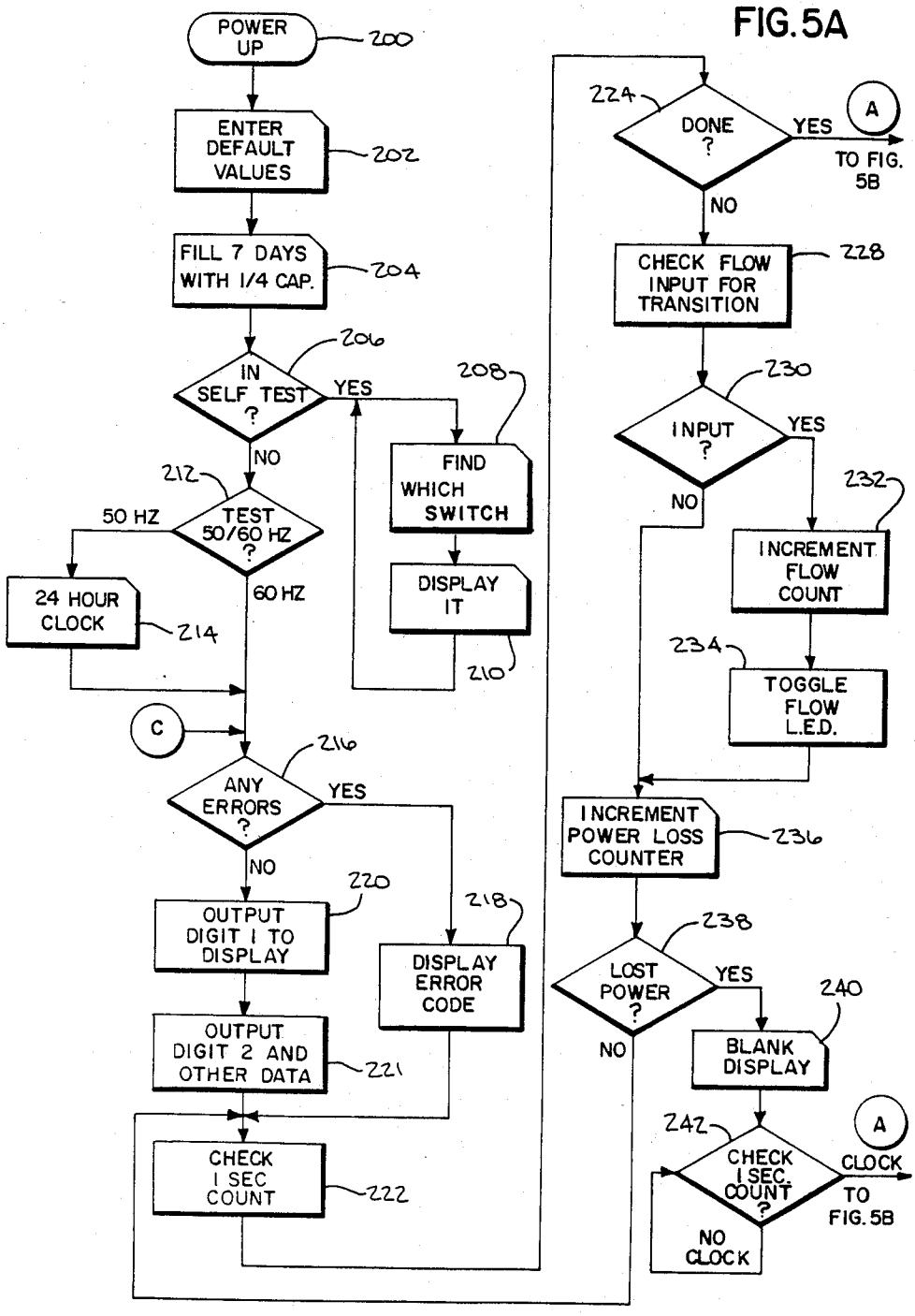

TO, FROM
CKT. 50
FIG. 4
111
118
110
119
112b
113b
116
112a
113a
114
117
236

FIG. 4a

FIG. 5A


POWER UP
200
ENTER DEFAULT VALUES
202
FILL 7 DAYS WITH 1/4 CAP.
204
IN SELF TEST ?
206
YES
208
FIND WHICH SWITCH
DISPLAY IT
210
NO
212
TEST 50/60 HZ ?
50 HZ
60 HZ
24 HOUR CLOCK
214
C
216
ANY ERRORS ?
YES
NO
218
DISPLAY ERROR CODE
220
OUTPUT DIGIT 1 TO DISPLAY
OUTPUT DIGIT 2 AND OTHER DATA
221
CHECK 1 SEC. COUNT
222
224
DONE ?
YES
A
TO FIG. 5B
NO
CHECK FLOW INPUT FOR TRANSITION
228
230
INPUT ?
YES
NO
232
INCREMENT FLOW COUNT
234
TOGGLE FLOW L.E.D.
INCREMENT POWER LOSS COUNTER
236
238
LOST POWER ?
YES
NO
240
BLANK DISPLAY
242
CHECK 1 SEC. COUNT ?
A
CLOCK
TO FIG. 5B
NO CLOCK

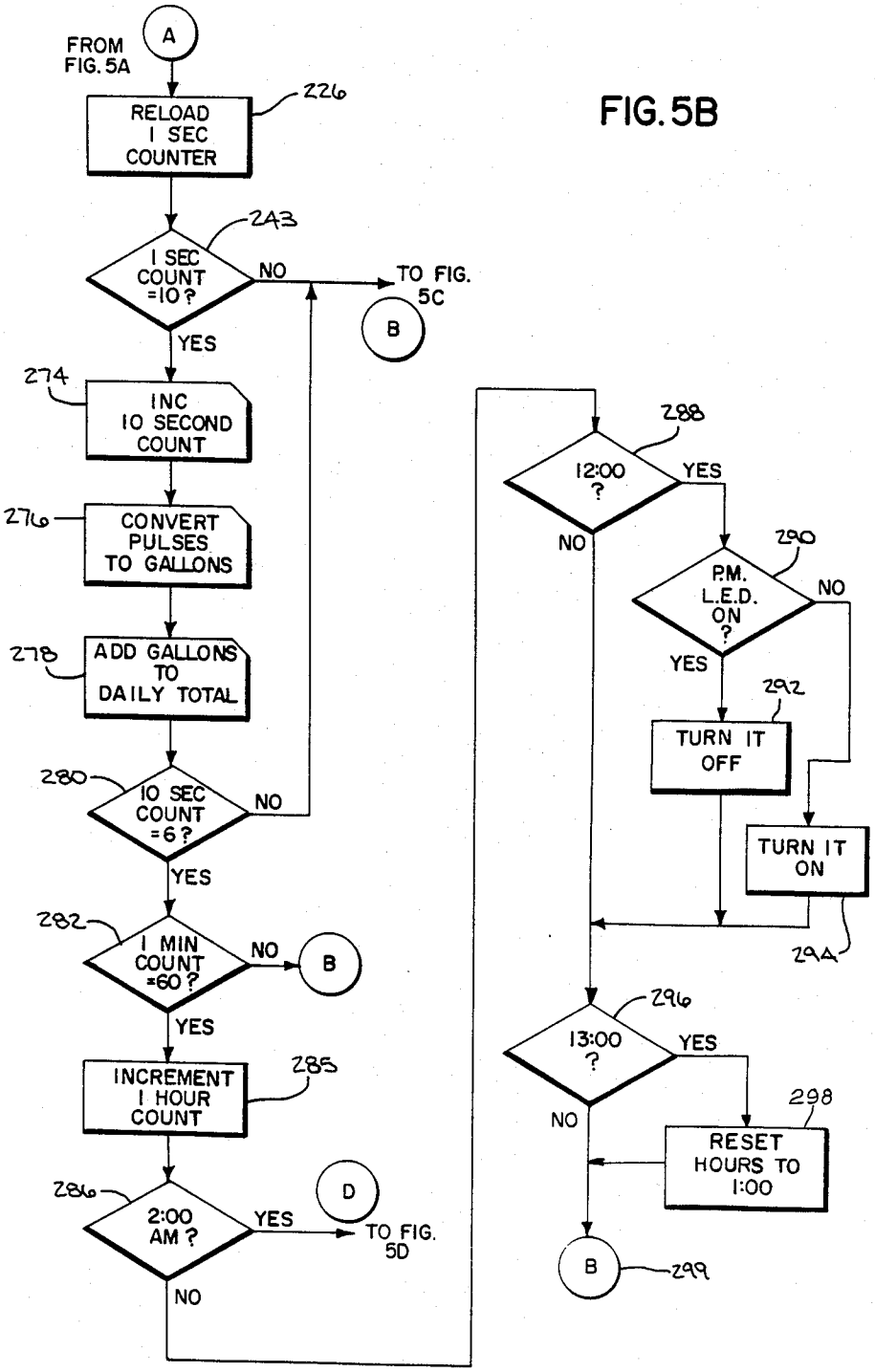

FROM FIG. 5A
A
RELOAD 1 SEC COUNTER
226
1 SEC COUNT =10?
243
NO
TO FIG. 5C
B
YES
INC 10 SECOND COUNT
274
CONVERT PULSES TO GALLONS
276
ADD GALLONS TO DAILY TOTAL
278
10 SEC COUNT =6?
280
NO
YES
1 MIN COUNT =60?
282
NO
B
YES
INCREMENT 1 HOUR COUNT
285
2:00 AM?
286
YES
D
TO FIG. 5D
NO
12:00 ?
288
YES
NO
P.M. L.E.D. ON ?
290
NO
YES
TURN IT OFF
292
TURN IT ON
294
13:00 ?
296
YES
NO
RESET HOURS TO 1:00
298
B
299

FIG. 5B

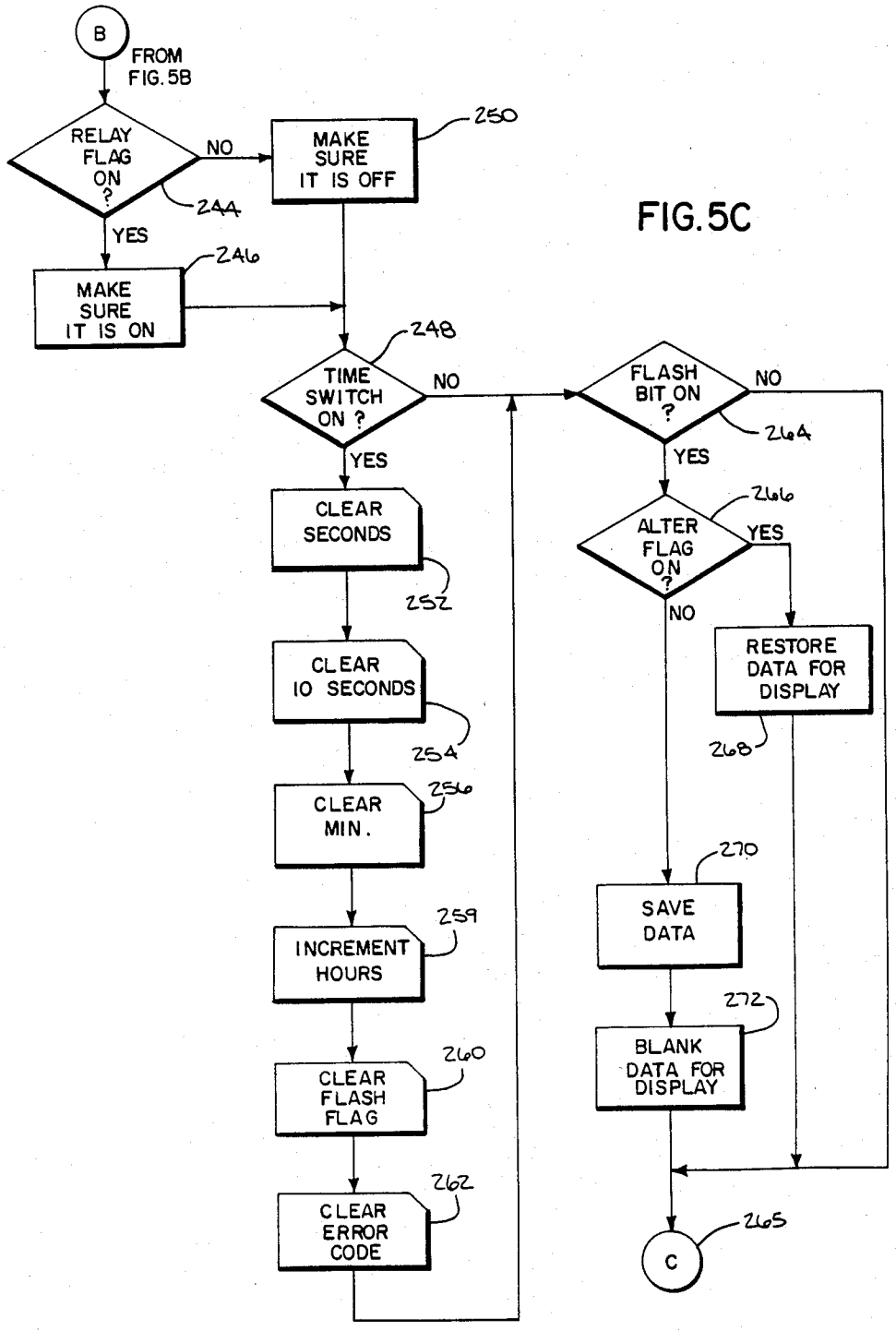

B
FROM FIG. 5B
RELAY FLAG ON ?
NO
YES
244
MAKE SURE IT IS OFF
250
MAKE SURE IT IS ON
246
TIME SWITCH ON ?
248
NO
YES
CLEAR SECONDS
252
CLEAR 10 SECONDS
254
CLEAR MIN.
256
INCREMENT HOURS
259
CLEAR FLASH FLAG
260
CLEAR ERROR CODE
262
FLASH BIT ON ?
264
NO
YES
ALTER FLAG ON ?
266
YES
NO
RESTORE DATA FOR DISPLAY
268
SAVE DATA
270
BLANK DATA FOR DISPLAY
272
C
265

FIG. 5C

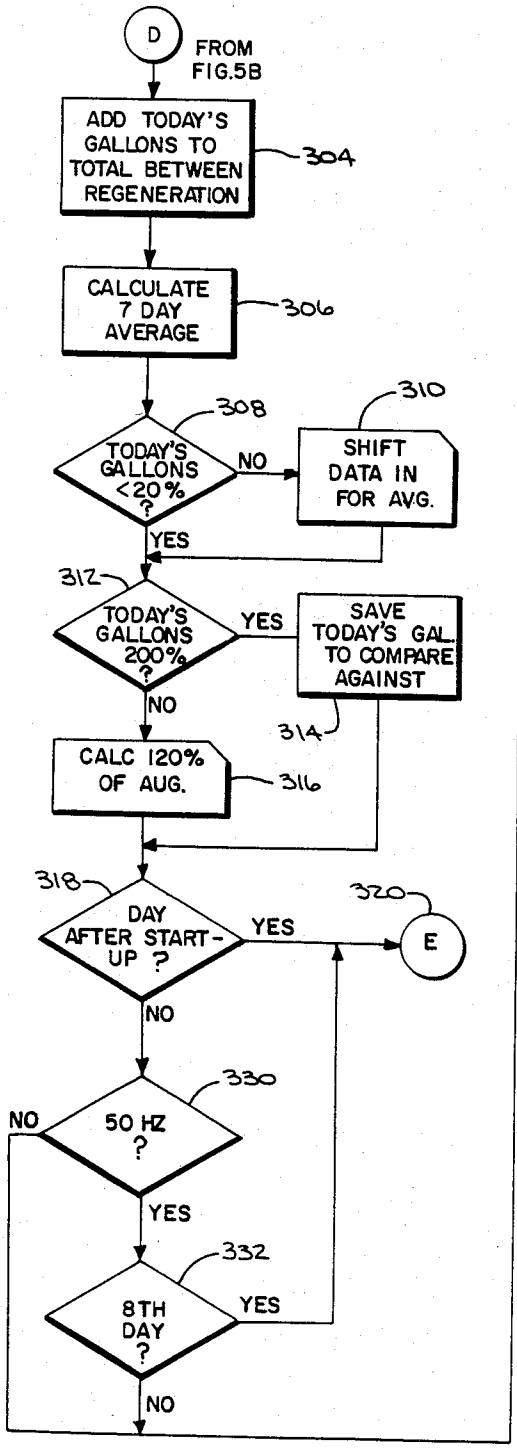
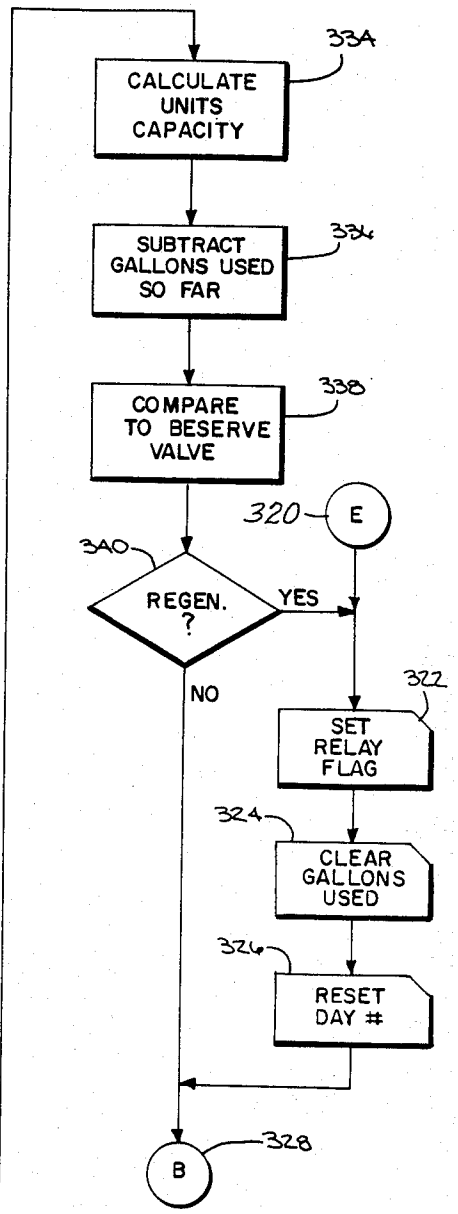

D
FROM FIG.5B
ADD TODAY'S GALLONS TO TOTAL BETWEEN REGENERATION
304
CALCULATE 7 DAY AVERAGE
306
308
TODAY'S GALLONS <20% ?
NO
SHIFT DATA IN FOR AVG.
310
YES
312
TODAY'S GALLONS 200% ?
YES
SAVE TODAY'S GAL. TO COMPARE AGAINST
314
NO
CALC 120% OF AUG.
316
318
DAY AFTER START-UP ?
YES
320
E
NO
330
50 HZ ?
NO
YES
332
8TH DAY ?
YES
NO

FIG. 5D


334
CALCULATE UNITS CAPACITY
336
SUBTRACT GALLONS USED SO FAR
338
COMPARE TO BESERVE VALVE
320
E
340
REGEN. ?
YES
NO
322
SET RELAY FLAG
324
CLEAR GALLONS USED
326
RESET DAY #
B
328

MICROCOMPUTER CONTROLLED DEMAND/SCHEDULED WATER SOFTENER

RELATED APPLICATIONS

This application is a continuation of U.S. patent application Ser. No. 412,279 filed Aug. 27, 1982, now U.S. Pat. No. 4,426,294.

BACKGROUND OF THE INVENTION

This invention relates generally to a control unit for a resin bed type water softener and more particularly to an improved microcomputer-based control unit for a resin bed water softener which initiates regeneration of the water softener resin bed only when necessary.

The most common type of water softener is the ion exchange resin-type softener having a tank which holds a bed of resin through which the hard water is passed to remove undesirable minerals and other impurities. The capacity of the resin bed to absorb minerals and impurities is finite and it is thus necessary to periodically recharge or regenerate the resin bed with a regenerant, typically a brine solution so as to restore the capacity of the resin bed for further water treatment.

With the earliest types of water softeners regeneration was effected manually only after it was discovered that the treatment capacity of the resin bed has been exceeded and the water flowing therethrough was no longer soft. In an effort to eliminate the need for manual regeneration, water softener control systems were developed utilizing a mechanical clock which initiated water softener regeneration on a periodic basis, the frequency of such regeneration being set in accordance with the known capacity of the resin bed and the anticipated daily usage of soft water. While mechanical clock-type water softener control units have alleviated the need for manually regenerating the water softener resin bed, such water softener control units are subject to the disadvantage that by regenerating the water softener resin bed at fixed intervals, regeneration may actually be occurring too often if actual soft water consumption is less than the anticipated soft water consumption or not often enough when the actual soft water consumption exceeds the anticipated soft water consumption. Regenerating the water softener resin bed when sufficient capacity still exists to treat an amount of water equal to, or in excess of the anticipated soft water consumption, is wasteful of salt and the water needed in regeneration. Conversely, failure to regenerate the water softener resin bed after the resin bed capacity has diminished to a point below that required to treat the actual quantity of soft water demanded results in hard water leaving the water softener.

In an effort to better regulate the frequency of water softener resin bed regeneration, demand-type water softener control units have been developed which sense the remaining capacity of the water softener resin bed to soften water. Most present day demand-type water softener control units operate to initiate regeneration of the water softener resin bed at an off-peak time, usually 2:00 a.m., if the remaining capacity of the water softener resin bed, as sensed by the control, is less than that required to refine the amount of water which would likely be used prior to the next regeneration interval. While demand-type water softener control units do achieve better regulation of water softener resin bed regeneration than do mechanical clock-type water softener control units, the frequency at which such demand-type water softener control units initiate regeneration is dependent on the selected reserve value representing the anticipated amount of soft water which will be used prior to the next regeneration interval. Since the actual amount of soft water used will likely not remain constant, but will vary greatly from day to day, the chosen reserve value must be made large to assure that soft water will always be produced by the water softener. Thus, regeneration will likely occur at a greater frequency than is actually necessary.

In contrast to the prior art mechanical clock-type water softeners which initiate regeneration on a periodic basis and prior art demand-type water softener control units which initiate resin bed regeneration in accordance with an artificially determined reserve value, the present invention concerns an improved microcomputer processor-based water softener control unit which initiates water softener regeneration when the remaining resin bed capacity as determined from the actual soft water consumption is less than a reserve value calculated in accordance with the actual soft water consumption to assure that the resin bed is regenerated only when necessary.

It is an object of the present invention to provide an improved water softener control unit which utilizes a microcomputer to control water softener resin bed regeneration.

It is another object of the present invention to provide an improved microcomputer based water softener control unit which controls water softener resin bed regeneration in accordance with the remaining capacity of the water softener resin bed to treat water.

It is yet another object of the present invention to provide an improved microcomputer-based water softener control unit which initiates water softener resin bed regeneration when the remaining resin bed capacity as determined from the actual soft water consumption is less than a reserve value calculated in accordance with the actual soft water consumption so that regeneration occurs only when necessary, thereby achieving a savings of regenerant and water.

BRIEF SUMMARY OF THE INVENTION

Briefly, in accordance with the preferred embodiment of the invention, I have provided a control for a water softener requiring periodic resin bed regeneration comprising a flowmeter for detecting the quantity of softened water leaving the softener. A data input device is also provided for receiving data indicative of the capacity of the resin bed and the hardness of the incoming water. Both the flowmeter and the data input device are coupled to a controller which determines the average daily consumption of soft water from the flowmeter data and which determines the remaining resin bed treating capacity from the flowmeter data and the data entered through the data input device. Once the remaining resin bed treating capacity is, the controller determines whether or not regeneration should occur by comparing remaining resin bed treating capacity to a reserve value established by the controller in accordance with the actual average consumption of soft water. If the remaining resin bed treating capacity is less than the established reserve value, then regeneration is initiated.

In accordance with another aspect of this invention, I have provided an improved method for controlling water softener resin bed regeneration commencing with

the steps of measuring the quantity of water leaving the softener over a given period of time and then determining the actual daily average quantity of soft water consumed and the amount of soft water used since the last regeneration in accordance with the measured amounts of soft water leaving the softener. Thereafter a reserve quantity of soft water is established from the calculated daily average of soft water consumption. The remaining water softener resin bed treating capacity is then calculated in accordance with the amount of soft water used since the last regeneration and the incoming water hardness. Water softener resin bed regeneration is effected when the remaining water softener resin bed treating capacity is less than the established reserve value.

In operation of my improved control, data from the flowmeter is monitored by the microcomputer and at a particular time each day, as determined by the clock, data representing the actual amount of soft water used during the previous 24 hour period is stored in the memory. Typically, seven consecutive values representing the actual daily soft water usage for each of the previous seven days are stored in the memory. After storing the soft water consumption data, the microcomputer first calculates the total amount of soft water used since the last regeneration from the data stored in memory and then determines the actual average daily soft water used by averaging the stored data representing actual soft water usage. Following calculation of the total amount of soft water used since the last regeneration, the microcomputer then calculates the remaining resin bed capacity by subtracting the amount of resin bed capacity depleted, as determined from the total amount of soft water used since the last regeneration and the water hardness, from the total water softener resin bed capacity. Having now calculated the remaining water softener capacity this value is then compared to a reserve value established by the microcomputer as a proportion of the determined actual average daily soft water usage. Typically, the reserve is calculated by multiplying the actual average daily soft water usage by 1.2. If the reserve is greater than the calculated remaining water softener capacity, then water softener regeneration is initiated. Otherwise, the microcomputer only updates the data received from the flowmeter and waits another 24 hours before repeating these calculations to determine whether or not regeneration should occur.

Furthermore, the advantage of the water softener control of the present invention can account for exceptional variations in soft water usage. If the usage during any one of the previous seven days is less than 20% of the calculated average, then that small value of soft water usage is not entered in memory as the daily usage but is added to the amount of soft water used since the previous regeneration. Also, should the previous day's, consumption exceed 200% of the average daily consumption, then that previous day's usage will be substituted as the reserve to assure that sufficient water softener resin bed capacity exists for the increased soft water usage.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, both as to organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in conjunction with the accompanying drawings in which:

FIG. **1** is a resin bed type water softener embodying the control of the present invention;

FIG. **2** is a side view of the control of the water softener illustrated in FIG. **1**;

FIG. **3** is a front view of the control of the water softener illustrated in FIG. **1**;

FIG. **4** is an electrical schematic diagram of the circuitry embodied in the control of the water softener illustrated in FIG. **1**; and

FIG. **4***a* is a cut away view of the water softener of FIG. **1** taken along lines **4***a*—**4***a*.

FIGS. **5**A through **5**D illustrate, in flowchart form, the program executed by the water softener control of the present invention during operation.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the Figures, FIG. **1** illustrates a resin bed-type water softener **10** which includes a tank **12** containing a resin bed **14**. As incoming hard water enters the tank through an opening (not shown) in the top thereof, the water in the tank is forced through the resin bed and out the draw pipe **16** extending through the center of the resin bed so that water exiting via the draw pipe has been treated by the resin bed to remove minerals and other impurities. The capacity of resin bed **14** to absorb the minerals and impurities of the incoming hard water is finite, and depends on the treating capacity of the resin in the tank as measured in kilograins of hardness as well as the hardness of the incoming water as typically measured in grains per gallon. To regenerate the resin bed, once its treating capacity has been depleted, the resin bed is flushed with a brine solution so that the minerals and other impurities can be released from the resin bed and carried out the tank. In practice, the brine solution is stored in a separate tank **18** and is admitted to the softener tank **12** during regeneration through a tube **20** and a air check valve **22**.

The control of brine flow into tank **12** from brine tank **18** as well as the control of hard water flowing into the tank via inlet **23***a* and the flow of soft water leaving the tank via outlet **23***b* is accomplished by a valve module **24** threaded on the top of tank **12** so as to be in communication with the tank inlet (not shown) and draw pipe **16**. Valve module **24** typically comprises a control body such as manufactured by Autotrol Corporation Glendale, Wis., under part No. 24N. As best illustrated in FIG. **2** valve module **24** includes seven disc-type valves **25***a* through **25***g*, respectively. In the present valve module, valves **25***e* and **25***f* are designated as the inlet and outlet valves, respectively as the valves **25***e* and **25***f* each regulate the flow of hard water into tank **12** from inlet **23***a* and the flow of soft water up from draw pipe **16** (FIG. **1**) out through to outlet **23***b*, respectively. Valve **25***g* serves to regulate the flow of brine from brine tank **18** into tank **12** and is therefore referred to as the brine valve. The valve **25***d* controls water flow in the valve module through a port (not shown) in communication with inlet **23***a* and outlet **23***b* so that when the inlet and outlet valves are closed, water may flow directly through the inlet and out the outlet while value **25***d* is open. The remaining valves **25***a*, **25***b* and **25***c* serve to control the flow of water and brine from the tank into a drain conduit **30** (FIG. **1**).

During a regeneration cycle, each of valves **25***a* through **25***g* is actuated at an appropriate interval by a separate one of the corresponding cams **26***a* through **26***g* carried on a cam shaft **28** when the cam shaft is rotated to bring the corresponding cam into contact with the valve. Cam shaft **28** is journaled at its rearend into a cam

shaft support **31** extending upwardly from the valve module. The forward (rightward) end of cam shaft **28** has a forwardly extending shank for engaging the "T" shaped slot in the rearward end of the outwardly extending shaft **32***a* of a gear **32** (FIG. **3**). As best illustrated in FIG. **3**, gear **32** is journaled for rotation within the cavity **33** of a control housing **34**. Returning to FIG. **2**, control housing **34** is slidably secured to the forward end of the valve module **24** by a pair of support guides **36** (FIGS. **1** and **2**) which each engage complimentary flanges (not shown) on the exterior of the control housing.

What has been described thus far with respect to the construction and operation of the valve module **24** is well known in the art.

The cavity **33** (FIG. **3**) within the forward end of the control housing **34** is closed by a cover **38** which is secured to the forward end of the control housing by screws **39** (illustrated in FIGS. **1** and **3**). Referring now to FIG. **3** which is a frontal view of control housing **34** showing portion of cover **38** cut away, cover **38** is generally opaque except for a window **40** which carries the indicia "PM" and "WATER FLOW". As will become clear hereinafter by reference to FIG. **4**, window **40** allows a display within the cavity to display certain information. Immediately below window **40** is a passageway **41** through the cover which has a spring biased button **42** protruding outwardly therethrough. As will also become clear by reference to FIG. **4**, button **42** is depressed to set the time displayed by the display through window **40**.

With a portion of cover **38** broken away in FIG. **3**, it can be observed that not only is gear **32** journaled within the cavity **33**, but an idler gear **44** is also journaled within cavity **33** and is in meshing engagement with gear **32**. Idler gear **44** is driven by a gear **46** which is carried on the forward end of the shaft of motor **48**, (FIG. **2**); the motor being mounted on the rear of the control housing so that its shaft extends through the control housing **34** and into the cavity to receive gear **46**.

Motor **48** of FIG. **2**, which is typically a 1 RPM A.C. clock motor, is energized with alternating current by a control circuit **50** of FIG. **4** (described hereinafter) when the control circuit determines, in accordance with a particular algorithm, that regeneration should be effected. Motor **48**, when energized from control circuit **50**, drives cam shaft **28** through gears **46**, **44** and **32** to cause cams **26***a* through **26***g* to actuate a corresponding one of valves **25***a* through **25***f*, respectively. The cams **26***a*–**26***f* are shaped such that valves **25***a* through **25***f* respectively are actuated in a particular sequence for a particular duration during a single revolution of the cam shaft so that the backwash, brining, slow rinse, and brine refill and purge steps, which are normally required to complete resin bed regeneration, are performed in the desired sequence. Following a single revolution of the cam shaft, the valves returned to the service position so as to allow normal water flow through the softener.

Although water softener resin bed regeneration is normally effected when control circuit **50** energizes motor **48**, there may be instances when manual regeneration is desired. To enable manual regeneration, gear **32** has a hub **52** extending forwardly of the gear and through an opening **54** (FIG. **1**) in cover **38**. Gear **32** and hub **52** are spring biased from shaft **32***a* so that when the hub **52** of the gear is pushed inwardly, gear **32** becomes disengaged from idler gear **44** so as to allow the cam shaft to be manually rotated upon rotation of the hub. As the hub is rotated either manually, or upon the gear **32** being driven the motor **48**, an arrow **55** on the hub points to indicia (not shown) on the face of cover **38** representing the various states of water softener operation, to indicate which step of the regeneration cycle is then being executed, or, whether valves are presently in the service position.

Protruding outwardly from the gear **32** is a member **56** which, as the gear rotates, comes into contact with the spring biased arm **57***a* of a leaf switch **57**. Leaf switch **57** is connected to control circuit **50** in a manner described hereinafter. The switch is actuated either by member **56** as the gear is rotated or when the hub is simply depressed since the outward force of the member **56** keeps the spring biased arm **57***a* from normally moving downwardly to actuate the switch. When switch **57** is actuated, the control circuit initiates regeneration. Thus, regeneration can be effected not only by manually rotating hub **52** but by simply depressing the hub to activate switch **57**.

The details of control circuit **50** are set forth schematically in FIG. **4**. At the heart of control circuit **50** is a data processing unit **58** which, in the presently preferred embodiment, takes the form of a single chip microcomputer such as a model 8048 microcomputer as manufactured by Intel Corp, Santa Clara, Calif. Microcomputer **58** includes "on-board" random access memory for storing data previously entered to the microcomputer or developed during the course of operation thereof. Also, the microcomputer includes on-board read only memory in which is stored the operating program to be described in greater detail with respect to FIGS. **5**A to **5**D. This program controls the operation of the internal microcomputer arithmetic logic unit which performs the necessary calculations and logic determinations, to decide whether regeneration should be effected. In addition to the on-board memory and the arithmetic logic unit, microcomputer **58** also includes an internal timer which serves as a real time clock. For a further, more complete description of the Model 8048 microcomputer, reference should be had to the "MCS-48 User's Manual" published by Intel Corporation.

A 5 volt regulated d.c. voltage to energize microcomputer **58** is supplied to the microcomputer at its Vcc pin by a power supply **59** comprised of a transformer **60** whose primary winding **60***a* is coupled to a supply of 110–220 volt, 50–60 Hertz a.c. supply (not shown). Because of the lack of space within the cavity **33** for the transformer, transformer **60** is mounted to the rear of the control housing as shown in FIG. **2**. The low voltage a.c. produced across the center tapped transformer secondary winding **60***b* when the primary is coupled the a.c. supply voltage, is rectified by a pair of diodes **61***a* and **61***b* whose anodes are each coupled to one of opposite ends of the transformer secondary winding **60***b*. With the diode cathodes connected together, an unregulated d.c. voltage appears between the junction of the diode cathodes, hereafter referred to as the power supply unregulated voltage (unreg) output terminal and the transformer center tap, hereinafter referred to as the power supply common (com) terminal.

The unregulated d.c. voltage present between the unregulated voltage and common terminals of power supply is filtered by a pair of parallel coupled capacitors **62***a* and **62***b* before being supplied to a voltage regulator

63. The 5 voltage regulated d.c. voltage produced at the output of the regulator, which is designated as the "+5 V" output of the power supply, is filtered by a pair of capacitances **64***a* and **64***b* coupled in parallel between the +5 V power supply terminal and the power supply common terminal before being supplied to pin Vcc of the microcomputer. Although the regulated 5 volt d.c. voltage produced by the power supply is well filtered, it is desirable to connect a filter capacitance **65** between microcomputer pin Vcc and the power supply common terminal. A completed circuit between the power supply and the microcomputer **58** is accomplished by connecting the microcomputer ground pin Vss to the power supply common terminal.

Within the microcomputer **58** is a master oscillator (not shown) whose periodic clock signals control the internal microcomputer timer and arithmetic logic unit. The frequency of this oscillator is determined from the reactance appearing across the microcomputer pins XTAL1, and XTAL2. In the presently preferred embodiment, this reactance is established by a inductance **66** coupled across the XTAL1, and XTAL2 pins of microcomputer **58** and a pair of capacitances **68***a* and **68***b* each coupled between a separate one of the microcomputer XTAL1, and XTAL2 pins and the power supply common terminal. The power supply common terminal is also coupled to the microcomputer pin EA to assure that during microcomputer operation, all memory accesses by the internal arithmetic logic unit in response to periodic timing signals from the internal master oscillator are made from the internal random access and read only memories of the microcomputer.

The internal timer of the microcomputer, which as indicated serves as a real time clock, is strobed or clocked in accordance with the alternations of the a.c. supply voltage. Since the a.c. supply voltage is accurately maintained either at 50 or 60 Hz depending on the custom, the frequency of alternations of the a.c. supply voltage can be used as a basis of measuring real time. To strobe the internal microcomputer timer, a clocking circuit **70** is provided for supplying microcomputer at its T1 pin with a logic level voltage which changes logic states in accordance with the alternations of the a.c. supply voltage. Clocking circuit **70** includes a diode **71** and a resistance **72** serially coupled between the one of the two secondary winding terminals of transformer **60** and the base of a first transistor **73** whose collector-to-emitter portion is coupled in series with a resistance **74** between the +5 V and common terminals of power supply **59**. Transistor **73** is also coupled at its base to the +5 V terminal of the power supply through a pair of serially coupled resistances **75***a* and **75***b*. Each time the a.c. voltage at the secondary **60***b* of transformer **60** undergoes an alternation, the transistor **73** is rendered conductive. A filter comprised of the parallel combination of a capacitance **76** and a resistance **77** filters stray noise to prevent false conduction of transistor **73**.

A second transistor **78** has its base coupled to the junction between resistance **74** and transistor **73** and transistor **78** has its collector-to-emitter portion coupled between the junction resistances **75***a* and **75***b* and the power supply common terminal. The conduction of transistor is controlled by transistor **73** and when transistor **73** is conductive, transistor **73** shunts current from the base of transistor **78** to keep transistor **78** from conducting. While transistor **73** is nonconductive, transistor **78** is supplied with base current and becomes conductive. In this way transistor **78** acts as a logic inverter so that the logic level voltage appearing across transistor **78**, which is supplied to the microcomputer at pin T1 to strobe the internal timer, will be logically inverse to the logic level voltage appearing across the collector-to-emitter portion of transistor **73**.

In order for the internal microcomputer timer to keep the correct time, the timer must usually be initially set to the appropriate time. Setting of the timer is accomplished by closing a switch **79** coupled between the microcomputer timing input at pin T_o and the power supply common terminal input to force the voltage at the timing input to a logic low voltage level. In practice switch **79** is activated by depressing button **42** (FIG. **3**) protruding through the cover **38** (FIG. **3**). While switch **79** is open, the timing input is maintained at a high logic level voltage via a resistance **80** coupled between the pin T_o and the +5 V power supply terminal.

Because the internal microcomputer timer counts time in accordance with the alternations of the a.c. supply voltage as processed by clocking circuit **70**, the microcomputer must be alerted as to whether the a.c. supply voltage frequency is 60 Hz. as is the case in the United States or 50 Hz. as is the case in many European countries. To alert the microcomputer as to the a.c. supply voltage frequency, a switch **81** is coupled between the second highest order microcomputer data bus line (7) which terminates at pin DB_7 and the power supply common terminal. After determining whether or not that bus is at a ground potential (i.e. whether or not switch **79** is closed) the microcomputer then knows whether the a.c. supply voltage is 50 or 60 Hz., respectively.

Normally, the microcomputer power is provided from power supply **59**, and the timing signal for clocking the internal timer is provided from the clocking circuit **70**. However, should the a.c. supply voltage fail, then not only does the clocking circuit fail to supply periodic pulses, but more importantly the internal microcomputer memories which store collected data may be erased. To keep at least the microcomputer memories from being erased, a battery **82** is coupled at its positive terminal via Zener diode **84** to the standby voltage input pin Vdd of the microcomputer **58**. The negative terminal of the battery is coupled to the power supply common terminal. While there is an a.c. voltage at the input to the power supply **59**, a regulated d.c. voltage is provided to pin Vdd from the power supply via a diode **86**.

Usually the battery voltage is less than the sum of the break over voltage of the Zener diode **34** and the voltage drop across diode **86** but is greater than the Zener diode break over voltage. Thus, only when the supply voltage fails will battery **82** render Zener diode **84** conductive and supply voltage to the microcomputer. Note that a capacitance could be substituted as an energy storage device in place of battery **82**. A capacitor **87** is connected between microcomputer pin Vdd and the power supply common terminal to filter any noise.

Once the a.c. supply does fail, resetting of the microcomputer is usually necessary. A reset circuit **90** for accomplishing resetting of microcomputer upon "power up" includes a resistance **92** and a Zener diode **94** coupled in series between the power supply unregulated voltage output terminal and the base of a first transistor **96** whose collector-to-emitter portion is coupled in series with a resistance **98** between the power supply unregulated voltage output terminal and the power supply common terminal. The base-emitter junc-

tion of the transistor is shunted by the parallel combination of a resistance **100** and a capacitance **102**.

A second transistor **104** has its base coupled to the junction between resistance **98** and transistor **96** and transistor **106** has it collector-to-emitter portion coupled in series with resistance **108** between the microcomputer reset input terminating at the RESET pin and the power supply common terminal. During intervals while a.c. is supplied to the power supply, transistor **96** is rendered conductive to divert current from the base of transistor **106** to keep it from conducting, thereby keeping the impedance at the microcomputer reset input high. However, once the a.c. supply voltage fails and then is reapplied to the power supply, transistor **96**, which had become nonconductive once the a.c. supply voltage failed, will not again become conductive until the unregulated output voltage of the power supply **59** reaches the threshold voltage of Zener diode **94**. In the meantime, with transistor **96** temporarily nonconductive, transistor **106** becomes conductive once the power is reapplied to provide a low impedance path between the microcomputer reset input and the power supply common terminal to reset the microcomputer.

As will become better understood by reference to flow chart FIGS. **5A–5D**, microcomputer **58** is programmed to initiate water softener resin bed regeneration when the remaining resin bed treating capacity, as determined from the amount of water used since the previous regeneration and the water hardness, is less than a reserve value calculated as a percentage of the actual average daily soft water consumption.

Input data representing the flow of softened water leaving resin tank **12** of FIG. **1** is supplied from a flowmeter **110** (FIG. **1**) disposed in the outlet **23***b* to the highest order line (**17**) of the first of the two ports of microcomputer **58** terminating at pin P_{17}. Referring now to FIG. **4***a*, which is a cut away view of the inlet **23***b* taken along lines **4***a*—**4***a* of FIG. **1**, flowmeter **110** is comprised of a turbine **111** having a magnet **112***a* embedded in the periphery of the turbine so that the south magnetic pole is facing radially outwardly.

A counterweight **112***b* is located in the turbine periphery opposite magnet **112***a* to balance the turbine. The turbine is journaled at its rightward most end by a first bearing **113***a* secured in a bearing strut **114** disposed in the rightward end of the outlet. Turbine **111** is journaled at its leftward most end by a bearing **113***b* carried in a bearing strut **116** that is disposed in the interior bore of a collar **117** which is dimensioned to be received in the leftward most end of the outlet. An O ring **118** is disposed in sealing engagement between the collar and the outlet to prevent water leakage. As water flows through the outlet, the force of the water drives the turbine **111**, so that the magnet passes a Hall Effect switch **119** disposed in a wall of the outlet adjacent to the turbine.

Returning now to FIG. **4**, Hall Effect switch **119**, which typically comprises a model UGN 3040 T. Hall Effect switch as manufactured by Sprague Electric Co., Concord, N.H., is coupled at its input terminal I and its ground terminal G to the +5 V and common terminal of the power supply. A capacitance **119***b* shunts the I and G input level to filter any stray noise. When energized in this manner, the Hall Effect switch generates a high logic level voltage at its output terminal each time the magnet of the turbine passes the switch. This voltage is supplied to the microcomputer at line **17** of the second microcomputer port terminating at the microcomputer pin P_{17}. By counting the number of voltage level transitions, the microcomputer can determine the turbine velocity which is directly related to the flow rate of water leaving the softener. A pull up resistance **119***c* couples the microcomputer pin P_{17} to the +5 V power supply terminal to prevent random noise from causing an erroneous flow measurement.

Input data indicative of the total treating or softening capacity of resin bed **14** of FIG. **1** and data indicative of the hardness of the incoming water is entered into the microprocessor through the low order lines (**0–5**) of the microprocessor data bus terminating, at pins DB_0 through DB_5 and through the four lower order lines (**20–23**) of the second microprocessor port which terminate at pins P_{20}–P_{23}. In practice, input data representing the total resin bed treating capacity is entered as a binary number by connecting the appropriate ones of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the fourth highest line (**14**) of the first microprocessor port terminating at pin P_{14}. The existence of a connection by way of an associated one of jumpers **120***a* between one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23}, and port pin P_{14} represents a binary 1 digit while the lack of a connection represents a binary zero digit. The most signficant digit of the two digit number representing incoming water hardness as measured in grains is also entered as a binary number by connecting an associated one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the third highest line (**15**) of the second microcomputer port terminating at pin P_{15} via one of jumpers **120***b*. The least significant digit of the two digit number representing the incoming water hardness is likewise entered as a binary number by connecting an associated one of data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to the second highest line (**16**) of the first microprocessor port terminating at pin P_{16} via an associated one of jumpers **120***c*. Since the incoming water hardness is entered as a two digit decimal number varying between 0 and 99, only four binary bits are required to represent each digit. Therefore only the four higher order data bus pins DB_2–DB_5 or the four port pins P_{20}–P_{23} need be jumpered to one of port pins P_{15} and P_{16} to enter the most significant and least significant digits of the water hardness data. The remaining pins can be jumpered to cause the microcomputer to execute certain self-test instructions.

Referring to FIG. **3**, each of pins DB_0–DB_5 and P_{14}–P_{16} and P_{20}–P_{23} of the microcomputer are connected to a separate one of the terminals of one of connector blocks **122***a*–**122***c* which are carried on the circuit board **124** to which the components of control circuit **50** are mounted. During water softener installation, the installer enters data indicative of the total treating capacity and the incoming water hardness by connecting the appropriate terminals of connector blocks **122***a*–**122***c* together with one or more of the appropriate jumpers **120***a*, **120***b* and **120***c*.

Returning to FIG. **4** if the microcomputer determines from the input flow meter data and the resin bed treating capacity and water hardness input data that regeneration is required, then the microcomputer outputs a high level logical voltage on the second highest order data bus line (**6**) terminating at pin DB_6. This voltage is supplied to the base of a transistor **124** which is also supplied with a regulated 5 volt d.c. voltage from the power supply via pull up resistance **126**. Transistor **124** has its collector-to-emitter portion coupled in series with a resistance **128** between the power supply com-

mon terminal and one of the light emitter input terminals L_2 of an optical triac **130** whose other light emitter input L_1 is coupled to the unregulated voltage output terminal of the power supply. When transistor **124** is rendered conductive by microcomputer **58**, the transistor provides a completed circuit path for current to pass in the light emitter of the optical isolator **130** to render the optical isolator conductive. Optical isolator **130**, when rendered conductive, provides a completed circuit path between each of its input terminals I_1 and I_2, which are supplied with an a.c. voltage, and one of output terminals M_1 and M_2, respectively, which are coupled to motor **48**. Thus, when transistor **124** is rendered conductive, the motor is energized with a.c. current to drive cam shaft **28** of FIGS. **1–3**, thereby initiating resin bed regeneration. To filter the voltage switched by optical triac **130**, a resistance **132** is coupled in series with a filter capacitor **134** across terminals M_1 and M_2 of the optical triac.

As will be recalled, a switch **57** (FIG. **3**) is positioned within cavity **33** so that the switch is actuated either upon depression of hub **52** and gear **32** or upon rotation of the gear. Returning to FIG. **4**, switch **57** has its contacts connected to collector and emitter of transistor **124**, respectively. Thus, when switch **57** is actuated, the switch shorts the collector-to-emitter portion of the transistor to energize the optical triac **130**.

In addition to the previously described subcircuitry of the control circuit **50**, the control circuit **50** also includes a display comprised of a pair of 7 segment light emitting diodes (L.E.D.'s) **134*a*** and **134*b*** for displaying not only the time of day as measured by the number of alternations of the a.c. supply voltage as recorded in the internal microprocessor timer, but also for providing an indication of soft water flow from the tank **12**. Both of L.E.D.'s display **134*a*** and **134*b*** are coupled to the +5 V and unregulated output voltage terminals of the power supply **59**. Each of the seven segments a–g of L.E.D. **134*a*** is connected via a separate one of pull up resistances **136*a*** through **136*g***, respectively, to a corresponding one of the outputs **01–07** of a display driver circuit **138** which typically comprises a model 74 LS 47 display driver such as manufactured by Texas Instruments, Dallas, Tex. In addition to being coupled to the +5 V and common terminals of power supply **59** so as to receive a regulated 5 volt d.c. voltage therefrom, display driver circuit **138** has its four input terminals I_1–I_4 coupled to a separate one of the four highest lines (**24–27**) of the second port of microcomputer **58** which terminate at microcomputer pins P_{24}–P_{27}, respectively. During execution of its internally stored program, microcomputer **58** outputs a four-bit binary signal at pins P_{24}–P_{27} representing the least significant digit of the hour of the day which is supplied to the display driver **138** which in turn energizes the appropriate segments of L.E.D. display **134*a*** to display this least significant digit of the hour of the day.

To enable control circuit **50** of the present invention to be utilized both domestically and internationally, it is desirable that L.E.D.'s **134*a*** and **134*b*** display the hour of the day either in a 12 hour fashion or a 24 hour fashion. To this end, segments a, d, e, and g of display **134*b*** are each coupled to the common terminal of the power supply through resistance **139** in series with a collector-to-emitter portion of a transistor **140**. Transistor **140** is coupled at its base to the power supply +5 V terminal via a pull up resistance **141** and is coupled to the third lowest order line (**12**) of the first port of the microcomputer terminating at pin P_{12} so as to receive a high logic level voltage therefrom at appropriate intervals during execution of the microcomputer program to energize L.E.D. segments a, d, e and g. Segment b of L.E.D. display **134*b*** is coupled to the power supply common terminal via a resistance **144** in series with a collector-to-emitter portion of a transistor **146**. Transistor **146** is supplied at its base with a regulated five volt d.c. voltage from the power supply through a pull up resistance **148** and is also supplied in its base with the logic level output signal appearing on the third lowest line (**13**) of the first port of the microcomputer which terminates at microcomputer pin P_{13}. Segment c of L.E.D. display **134*b*** is switchably connected by the first contactor **150A** of a double pull, double throw switch **150** to resistance **144**. The second contactor **150*b*** of double pull, double throw switch **150** couples one terminal of a resistance **152**, between the decimal point segment d.p. of the L.E.D. display **134*b*** and segment c of light emitting diode **134*b***. The other terminal of resistance **152** is coupled by the collector-to-emitter portion of a transistor **154** to the power supply common terminal. Transistor **154** is supplied at its base with the five volt regulated d.c. output voltage of the power supply via pullup resistance **155** and is also supplied at its base with the logic level voltage of the second lowest order line (**11**) of the first microcomputer port terminating at microcomputer pin P_{11}. When switch **150** is set at the "12 Hr" position so that the decimal point segment d.p. of display **134*b*** is coupled to resistance **152** and segment c is coupled in parallel with segment b, then when transistor **154** is rendered conductive as a result of a microcomputer generating a logic high voltage at pin P_{11}, which is the case during the p.m. hours of the day as determined by the internal microcomputer timer, decimal point segment d.p. of light emitting diode display **134*b*** is energized. Once energized, the decimal point segment d.p. illuminates the indicia "PM" on the outer face of window **40** of FIG. **3** to indicate the hourly time displayed by L.E.D. displays **134*a*** and **134*b*** is after noon. With switch **150** in the "12 Hr" position, a "1" is displayed by L.E.D. display **134*b*** when transistor **146** is rendered conductive by the microcomputer. This will occur when the time of day, as determined by the internal microcomputer timer, is between either noon and 1:00 p.m. or midnight and 1:00 a.m.

If, however, switch **150** is set at the "24 Hr" position so that transistor **154** now drives segment c of L.E.D. display **134*b***, then, L.E.D. **134*b*** displays a "1" when both transistor **154** and transistors **146** are rendered conductive to energize segments b and c. This will occur when the microcomputer outputs a logical high level voltage at pins P_{13} and P_{11} during the interval when the time of day is between 1200 and 100 hours. During the interval when the time of day, as determined by the internal microcomputer timer, is between 2000 hours and 2400 hours, then the microcomputer outputs a logic high level voltage at both pins P_{13} and pin P_{12} so that segments a, d, e, and g are energized by transistor **140** and segment b is energized by transistor **146** to display a "2" at display **134*b***.

L.E.D. **134*a***, like display **134*b*** is also provided with a decimal point segment d.p. which is linked via a resistance **158** to the lowest order line (**10**) of the first microcomputer port terminating at pin P_{10}. During intervals other than when regeneration is occurring that is, during intervals when soft water is flowing through resin bed **14** of FIG. **1** and out outlet **23*b*** of FIG. **2**,

then, microcomputer **58** outputs a logic level voltage at pin P_{10} which alternate between a high and low logic level to alternately energize the decimal point segment d.p. of L.E.D. display **134***a*. Decimal point segment d.p. of display **134***b* appears behind the indicia "WATER FLOW" on window **40** of FIG. **3** so that while water is flowing through the softener, the decimal point segment d.p. of L.E.D. **134***a* flashes.

As indicated previously, within the internal memory of microcomputer **58** of FIG. **4** is a program which controls the microcomputer to enable the microcomputer to process the incoming data to determine whether or not motor **48** of FIGS. **2** and **3** should be energized to initiate regeneration as well as to enable the microcomputer to display the time of day on L.E.D. displays **134***a* and **134***b* of FIG. **4**.

PROGRAM START UP—STEPS 200–206

Referring now to FIGS. 5A through 5C which illustrate in flow chart form the program executed by the microcomputer and in particular FIG. 5A, execution of the microcomputer program is commenced (Step **200**) when power is applied to the microcomputer. Following program startup, a default value for the time of day is entered into the register of the internal microcomputer timer for time keeping purposes (Step **202**). Typically, this default value is "12 noon." However, the default value can be incremented while switch **79** of control circuit **50** is actuated so that if the correct hour of the day is other than 12 noon, then the appropriate value can be entered into the timer register. Following entry of the default value into the timer register, seven separate memory locations of the microcomputer internal memory are each filled with a value representing $\frac{1}{4}$ of the total refining capacity of resin bed **14** of FIG. **1**, as measured in gallons (step **204**). Since the microcomputer of the present invention operates to initiate water softener regeneration when the actual treating capacity of resin bed **14** of FIG. **1** is less than a reserve quantity calculated in accordance with the actual average daily soft water consumption, the entry of finite artificial values for the daily amount of soft water consumed in place of the value 0 enables the microcomputer to better regulate the frequency of water softener regeneration during the first week of operation. Each of the seven artificial values representing the daily consumption of soft water used for a particular day of the week is, however, replaced with the actual value of the daily consumption of soft water as determined from the flow meter during later operation of the water softener control.

SELF TEST MODE STEPS 206–210

Following entry of each of the seven artificial values which initially represent the amount of soft water used for each of the seven days of a week, the microcomputer **58** then checks whether it is operating in a self test mode (Step **206**). During installation as well as during intervals when the operation of microcomputer **58** is to be evaluated, the microcomputer is placed in a self test mode by jumpering certain of the microcomputer data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to one of port pins P_{14}, and P_{15}. If the microcomputer is operating in the self test mode, then the microcomputer checks to see which of any of the switches connected thereto, such as switches **150** and switch **136**, have been actuated (Step **208**). Should a particular switch be actuated, then a particular code representing the switch is displayed (Step **210**).

DISPLAY OF TIME OF DAY—STEPS 212–222

Once the microcomputer **58** has determined that it is not operating in the self test mode, the microcomputer examines the conduction state of switch **81** to determine whether or not the incoming a.c. supply to the primary of transformer **60** is at 50 or 60 hertz (Step **212**). The frequency of the a.c. supply voltage is important since the internal timer of microcomputer **58** is clocked in response to the alternations of the a.c. power supply voltage. If frequency of the a.c. input voltage is 50 hertz, then, microcomputer **58** operates light emitting diode displays **134***a* and **134***b* (FIG. **4**) as a 24 hour clock (Step **214**), assuming that switch **150** has been set to the "24 hour" position. In a location where the frequency of the a.c. supply voltage is 50 hertz, time is usually measured in 24 hour fashion rather than a 12 hour fashion. Following either a determination that the a.c. supply voltage is 60 hertz, or following the operation of the L.E.D. **134***a* and **134***b* (FIG. **4**) in a 24 hour clock mode, microcomputer **58** checks to see whether or not there are any errors (Step **216**), such as a failure to establish values for the total resin bed treating capacity and the incoming water hardness. Detection of an error results in a code indicative of the errors being displayed on L.E.D.'s displays **134***a* and **134***b* (Step **218**). Otherwise, if no errors are detected, then the microcomputer causes L.E.D. **134***b* to display the least significant digit of the hour of the day (Step **220**) and causes L.E.D. display **134***a* to display the most significant hour of the day (Step **221**).

TIME KEEPING AND FLOW DETECTION—STEPS 222–234

After displaying either the time of day, assuming that no errors exist, or after displaying the error code, the microcomputer then checks the one second count recorded by the internal microcomputer timer (Step **224**). When the microcomputer has completed this task, that is to say that the lapse of one second has been recorded by the one second register then, the microcomputer branches to program block A and reloads the one second register (Step **226**) as indicated in FIG. **5B**. Otherwise, while the microcomputer is waiting for one second to elapse, the microcomputer checks the flow meter (Step **228**) by inputting the logic level output voltage of the flow meter. The output logic level voltage of the flow meter is compared to a reference level stored in memory (Step **230**). A determination that the logic level voltage produced by the flow meter equals the stored reference value is indicative of the passage of water through the flow meter. In response an internal microcomputer counter storing a count representative of a passage of a certain quantity of water through the flow meter during a given interval is incremented (Step **232**) and thereafter, the decimal point segment d.p. of light emitting diode display **134***a* (FIG. **4**) is energized or toggled (Step **234**) to indicate water flow through the softener.

POWER LOSS DETECTION—STEPS 236–242

Following a determination that the output logic level voltage of the flow meter has not changed states, or following toggling of the L.E.D. display decimal point segment, an internal microcomputer register designated as a "power loss" counter is incremented (step **236**).

This register is referred to as a power loss counter because its count continues to be incremented during the period while the microcomputer is awaiting its internal timer to record the lapse of one second. Failure of the power loss counter to be incremented indicates failure of the internal microcomputer timer to record the passage of one second, thus indicating a loss of a.c. power. By checking the count of the power loss counter, (Step **238**) a power loss can be detected. If the count of the power loss counter has not been incremented, as determined during Step **238**, a power failure has occurred and the microcomputer then blanks the display of light emitting diodes **134***a* and **134***b* of FIG. **4** (Step **240**) to conserve on power.

After the display has been blanked, the microcomputer checks whether the internal microcomputer timer has resumed counting (Step **242**) and continues to check until the internal microcomputer timer records the passage of one second as will normally occur once power is reapplied to the microcomputer. Upon a determination that one second has elapsed, the microcomputer branches to program block A (FIG. **5B**) and the one second register is reloaded (Step **226**). However, after checking the power loss counter (Step **238**), if no power loss has been detected, then the microcomputer branches to step **222** to recheck the one second register to determine whether or not one second has elapsed.

TIME SETTING—STEPS 244–265

Referring to FIG. **5B**, following completion of checking the one second register (step **224**) and reloading of the register (step **226**), the microcomputer determines whether or not the internal microcomputer timer ten second register has counted out the passage of ten seconds (step **243**) after the one second register has been reloaded. If ten seconds have not elapsed, the microcomputer branches to block B and determines whether or not the relay flag has been set (step **244**) as illustrated in FIG. **5C**. As will become better understood by reference to the remaining steps of the program, once the microcomputer determines that regeneration should occur, microcomputer **58** sets a relay flag causing a high logic voltage to appear at microcomputer data bus pin DB_7 in response to which, transistor **124** of FIG. **4** is rendered conductive to energize the optical triac **130** of FIG. **4**. The optical triac then energizes motor **48** (FIG. **2**) to drive cam shaft **28** (FIGS. **1** and **2**) to initiate regeneration. After regeneration is initiated by setting of the relay flag, the relay flag remains set for ten minutes to assure that the optical triac keeps motor **48** of FIG. **2** energized. Once the motor has been energized to drive the cam shaft **28** of FIGS. **1** and **2** via gears **46**, **44** and **32**, the switch **57** is kept closed by the rotation of the gears to keep the motor energized well after the 10 minutes has elasped so that the entire regeneration cycle, which usually takes between 1–2 hours will be completed.

Returning to FIG. **5C**, if the relay flag has been set, or is "on" the microcomputer makes sure that the relay flag has been set (step **246**) before determining whether or not switch **79** of FIG. **4** has been closed (step **248**) to set the time displayed by light emitting diodes **134***a* and **134***b* of FIG. **4**. Alternatively, the microcomputer makes sure that after having not detected a set relay flag, that no flag was in fact set (step **250**) before checking to see whether switch **79** is closed to alter the displayed time (step **248**).

Following the determination that switch **79** has been closed to set the time display by the light emitting diodes **134***a* and **134***b* of FIG. **4**, the microcomputer then clears the internal microcomputer timer one second register recording the number of elapsed seconds (step **252**). Thereafter the microcomputer then clears the timer ten second register recording the number of ten second intervals that have elapsed (step **254**). Next, the microcomputer clears the register recording the number of 60 second or one minute intervals that have elapsed (step **256**) before the microcomputer increments the register of the internal microcomputer timer which records the passage of hours (step **258**).

Upon incrementation of the hour-register of the internal microcomputer timer, a "flash" flag is reset (step **260**) before clearing the register storing the error codes (Step **262**). The purpose of the flash flag will be explained below. After, either the microcomputer has cleared the error code register (step **262**) or after the computer has determined that the time switch **79** of FIG. **4** has not been closed (Step **248**), the microcomputer determines whether the flash flag has been set (Step **264**). During execution of the presently described program, an internal flag within the microcomputer referred to as the "flash flag" is alternately set and reset every second. As will become clear immediately hereinafter, the alternation of the state of the flash flag causes the display of light emitting diodes **134***a* and **134***b* to flash on and off during alternate seconds. A determination that the flash flag was unset when checked during step **264**, causes the microcomputer **58** to execute a jump instruction (step **265**) to branch to program block C so that step **216** is re-executed after which either the appropriate error code is displayed (Step **218**) or if no error exists, then the time of day is displayed on LED **134***a* and **134***b* of FIG. **4**. (Steps **220** and **221**). However a determination that the flash flag is set, causes the microcomputer **58** to check to see whether another flag, referred to as the "alter flag", has been set (Step **266**). This flag is set each time the time of day data to be displayed by the light emitting diodes has been altered or changed as will occur when the hour of the day has changed. When the alter flag has been set, then the altered time of day data to be displayed, is stored in microcomputer memory in place of the previous time of day data (Step **268**) and jump step **265** is then executed so that program control branches to step **216**. If the alter flag has not been set, then the time of day data is stored (step **270**) in a section of memory other than that associated with the data to be displayed on the light emitting diode display and data representing a blank display is moved into the memory location where the time of day data to be displayed is usually stored (step **272**) before jump step **265** is executed. When data represented a blank is stored in this memory location of the microcomputer memory, and when steps **220** and **222** are executed, neither of light emitting diode displays **134***a* and **134***b* are energized, so as to effectively display a blank.

WATER FLOW CALCULATION AND TIME UPDATE—STEPS 274–298

Returning now to FIG. **5B**, when the internal microcomputer timer has in fact counted ten seconds, then the program branches to step **274** after the ten second register has counted out rather than to step **244** as was described previously. Upon execution of step **274**, the micrcomputer increments the ten second register. Fol-

lowing incrementation of the ten second register, the previously stored count representing the number of transitions of the logic level of the flowmeter output voltage is converted into gallons (Step **276**) This is accomplished by multiplying the flowmeter output voltage transition count by a constant. The constant is actually a conversion factor which equals the number of gallons flowing past the flowmeter during the interval betwen each transition of the flowmeter output voltage. The calculated amount of soft water that left the softener during the 10 second interval is added to the previously calculated daily volume of soft water already stored in memory (step **278**) to keep an ongoing record of the amount of soft water passing through the softener for that day. Thereafter, the microcomputer checks whether the ten second counter has counted out six times thus indicating the passage of a minute (step **280**). If the ten second timer has not counted out six times, then the microcomputer jumps to program block B to re-execute step **244** and those following it described previously to make sure that the relay flag is set or not set and then to cause the time of day to be flashed on the L.E.D.'s **134***a* and **134***b* of FIG. **4**.

When, however, the ten second register of the internal microcomputer timer has in fact counted out six times indicating the passage of a minute, then the microcomputer checks the 60 minute register to determine whether or not the number of minutes that have been counted equals sixty (step **282**) indicating the passage of an hour. The microcomputer will execute a jump instruction (step **283**) to branch to block B of the program if an hour has not elapsed so that the microcomputer commences re-execution of step **244**. Otherwise, if the number of minutes counted does equal sixty, then the hour register which counts the number of hours that have elapsed is incremented by one (step **285**).

Following incrementation of the hour register the microcomputer then determines whether or not the particular time of day as determined by the count of the hour counter is 2:00 a.m. (step **286**) so tthat the microcomputer can determine whether or not regeneration should occur at this off-hour. Should the time not be 2:00 a.m., then the microcomputer checks the count of the hour register to determine whether or not the count of the hour register is twelve which would indicate a time of either 12:00 noon or 12:00 midnight (step **288**). Upon a determination that the count of the hour counter was 12, the microcomputer then checks whether or not the decimal point segment d.p. of light emitting diode **134***a* of FIG. **4** was previously energized (step **290**). If, at the time the count of the hour register equals 12 the microcomputer has determined that the decimal point segment d.p. of L.E.D. **134***a* of FIG. **4** was previously on, indicating that the time of day was after 11:00 p.m. but before 12:00 midnight, then the decimal point segment d.p. is turned off (step **292**) indicating that the time is now after midnight and before noon. However, if the decimal point segment d.p. of the light emitting diode **134***a* had previously been off or de-energized before the count of the hour register reached twelve, then after the hour counter has counted twelve, the decimal point segment d.p. of light emitting diode display **134***a* is turned on (step **294**) to indicate that the time is now post meridian rather than antimeridian.

When the microcomputer has determined that the hour register has not counted twelve during step **288**, then, the hour register is checked to determine whether or not the number of hours counted equals thirteen (step **296**). A count of **13** requires that the number of hours counted by the hour register be reset to one (step **298**) before the program executes jump instruction **299** to branch the to program block B to re-execute step **244**. Otherwise if the count of the hour register is other than thirteen, then the program executes jump instruction **299** to branch to step **244** directly without resetting of the hours register.

DECIDE IF REGENERATION IS REQUIRED—STEPS 285-324

Should the microcomputer determine during execution of step **286** that the time of day is 2:00 a.m. or such other offhour time as designated for regeneration, then the microcomputer proceeds to determine whether or not regeneration should occur by branching to block D and executing the following steps illustrated in flow chart form in FIG. **5D**. First, the total number of gallons used during the just elasped 24 hour period, as determined during execution of steps **260–264**, are added to the total number of gallons used since previous regeneration (step **304**). Thereafter, the average daily amount of soft water used over the past seven days (excluding the just elapsed day) is calculated (step **306**) by summing the seven separate values which each represent the soft water consumption for each of the past seven days and then dividing the total sum by seven. Once the average of the daily comsumption of soft water is calculated, this average value is compared to the previous day's total consumption (step **308**). If the previous day's consumption is greater than 20% of the average daily consumption, then the previous day's usage is stored in memory as the amount of water consumed for that day causing each of the daily stored values of the water consumption to be shifted in memory to now represent one earlier day's usage (step **310**) before proceeding to the next step. Note that the earliest day's usage will be erased. However, when the previous day's usage is less than 20% of the average daily consumption, then the amount of water used during the previous day is stored to enable it to be added to the total amount of water used between regenerations during the next execution of the program, but the previous day's consumption is not stored in memory as the amount of soft water consumed during that day so that no data shifting occurs. In this way, an unusually low daily consumption of soft water is ignored to avoid a zero average daily consumption of soft water such as might occur during intervals of non usage such as during vacations.

Following execution of step **310**, or following execution of step **308** if the consumption for a given day is less than 20% of the average daily consumption, the microcomputer then checks whether or not the previous day's consumption was greater than 200% of the average daily consumption (step **312**). Should the previous day's consumption of soft water be 200% greater than the seven day average consumption of soft water due to a sudden increase in water consumption which may result from the arrival of weekend guests for example, then this previous day's usage is stored in memory as a reserve value (step **314**). This reserve value represents the total amount of soft water likely to be consumed during the next 24 hour interval before the microcomputer will again make a determination as to whether or not regeneration is necessary. Otherwise the reserve value is determined as a percentage of the calculated

seven day average (step **316**). Typically, if the previous day's consumption is less than 200% of the calculated average, the reserve calculated during step **312** is obtained by multiplying the seven day average by 1.2.

After the reserve is established, either during execution of step **314** or step **316**, depending whether the previous day's consumption was greater than or less than 200% of the calculated seven day average, respectively, then the microcomputer checks whether or not the particular day of the week is the first day following start-up after a power failure (step **318**). If the day happens to be the first day following start up after a power failure, then the microcomputer initiates regeneration by executing jump instruction **320** to branch to program block E so as to execute instruction **322**. Step **322**, when executed, causes the microcomputer to set the previously described relay flag which results in the energization of motor **48** of FIGS. **1** and **2** to initiate regeneration of the water softener. In this way regeneration always occurs the first day after a power failure to assure that soft water always leaves the softener which may not otherwise occur if a large quantity of soft water is consumed during the power failure. After the relay flag has been set, then the memory location within the internal microcomputer memory storing the data representing the number of gallons used since the previous regeneration is cleared (step **324**). Once this memory location has been cleared, the internal microcomputer register which keeps track of the number of days between regeneration intervals is reset (step **326**). Thereafter, the microcomputer executes jump instruction **328** so that microcomputer program branches to program block B to step **244** FIG. **5C** which is then executed in the manner described previously.

If, however, more than one day has elasped since start up of the microcomputer following a power failure, then jump instruction **320** is not executed but rather the microcomputer branches to step **330** during which step the microcomputer checks to see whether the frequency of the incoming power is 50 H_z. If the frequency is 50 H_z, then the microcomputer checks to see whether 8 days have elapsed since the last regeneration (Step **332**). Should the count of a register recording the number of days since regeneration be 8 or greater, indicating that 8 or more days have elapsed since the previous regeneration, then the microcomputer will execute jump instruction **320** to branch control to program block E and instruction **322** which, when executed initiates water softener regeneration. In this way, regeneration is automatically effected every 8 days if no previous regenerations have occurred as is sometimes required by the health laws of countries foreign to the United States.

When the microcomputer has determined that the power frequency is not 50 H_z or if the power frequency is 50 H_z but 8 days have not elapsed since the previous regeneration, then the microcomputer proceeds to execute step **334** to calculate the total treating capacity of resin bed **14** in gallons. Such a calculation is accomplished by dividing the resin bed water treating capacity as measured in kilograins, (previously entered in the microcomputer by jumpering one or more of the microcomputer data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to port pin P_{16}) by the incoming water hardness, as measured in grains/gal., (which has previously added to the microcomputer memory by jumpering one or more of the microcomputer data bus pins DB_0–DB_5 and port pins P_{20}–P_{23} to port pins P_{15} and P_{14}). After the total water softener resin bed treating capacity has been calculated, the quantity of water consumed since the last regeneration is subtracted from the total water softener resin bed treating capacity (step **336**) to yield a value representing the remaining water softener resin bed treating capacity. The value representing the remaining water softener capacity is then compared to the reserve value (step **338**) previously calculated during either during step **314** or step **316**. Following comparison of the reserve value to the calculated value representing the remaining water softener resin bed treating capacity, the microcomputer then determines whether or not regeneration should occur (step **340**). If the reserve value as previously calculated during either step **314** or step **316** is greater than the remaining water softener resin bed capacity so that it is highly improbable that the water softener would be able to treat that amount of soft water likely to be consumed during the next 24 hour interval, then regeneration is effected by branching to step **322** to cause the relay flag to be set and motor **48** of FIGS. **1** and **2** to be energized. Otherwise, the remaining water softener capacity calculated during step **334** is greater than the reserve calculated during either of steps **314** or **316**, and no regeneration need be effected. In this event the microcomputer executes jump instruction **328** to branch to program block C and step **216**. Following execution of step **216**, the microcomputer then executes an appropriate sequence of steps **220–265** in the manner described previously.

Execution of the above described program occurs continuously during operation of the water softener without any need for manual intervention. Once the initial input data of the water softener resin bed refining capacity in kilograins and the incoming water hardness as measured in grains per gallon is entered to the microcomputer memory, no further adjustments need be made. Even a power outage will not totally prevent execution of the internal microcomputer program controlling the water softener although it is necessary for power to be resumed in order for the control circuit **50** to effectively control water softener regeneration.

Although the control circuit of the present invention has been described for use with a resin bed water softener, it is equally useful for controlling other types of water treatment devices having a filter bed requiring periodic regeneration.

The foregoing describes an improved control circuit for a water softener for controlling regeneration of a water softener resin bed in accordance with the actual average daily consumption so as to prevent the water softener from regenerating too often or not often enough.

While only certain preferred features of the invention have been shown by way of illustration, many modifications and changes will occur to those skilled in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as will fall within the true spirit of the invention.

What is claimed is:

1. A control for a water treatment device having a particle bed comprising:

a flow meter for measuring the amount of treated water leaving the water treatment device;

a data input device for entering data indicative of the total treating capacity of the water treatment device; and

a controller coupled to said flow meter and to said data input device for determining the remaining particle bed treating capacity in accordance with a prescribed relationship between the amount of treated water leaving the softener since the last regeneration and total particle bed treating capacity, said controller setting a treated water reserve representing the anticipated treated water usage and dynamically updating said reserve value each day, and said control initiating regeneration at a set time each day if said treated water reserve exceeds said remaining particle bed treating capacity.

2. The water softener control according to claim 1 wherein said controller sets said treated water reserve in accordance with the number of days since the previous regeneration.

3. The water softener control according to claim 1 wherein said controller sets said treated reserve as a proportion of the average amount of water anticipated to be used each day.

4. The water softener control according to claim 1 wherein said controller includes a microcomputer for setting said treated water reserve and for dynamically updating said reserve each day.

5. The water softener control according to claim 1 wherein said controller further includes a display for displaying the time of day.

6. The water softener control according to claim 1 wherein said controller includes manually activated means for initiating regeneration.

7. A control for a water softener having a particle bed comprising

a flow meter for measuring the amount of treated water leaving the water treatment device;

a data input device for entering data indicative of the total treating capacity of the water treatment device; and

a controller coupled to said flow meter and to said data input device, said controller establishing a treated water reserve in accordance with the number of days since the previous regeneration and dynamically updating said reserve value each day, and said controller initiating regeneration of the particle bed if the treated water reserve exceeds the remaining treating capacity of the particle bed.

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 4,490,249

DATED : December 25, 1984

INVENTOR(S) : J. David Seal

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Col. 2, line 58, "capacity is, the" should read --capacity is calculated, the--.

Col. 9, line 3, "transistor 104" should be --transistor 106--.

Col. 9, line 5, "has it collector" should be --has its collector--.

Col. 13, line 2, "alternate between" should be --alternates between--.

Col. 17, line 40, "so tthat" should be --so that--.

Signed and Sealed this

Eighth Day of *October 1985*

[SEAL]

Attest:

Attesting Officer

DONALD J. QUIGG

Commissioner of Patents and Trademarks—Designate